MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2015/2016

EOP3026 – OPTOELECTRONICS DEVICES

(Nano, Optical)

13 OCTOBER 2015
09.00 – 11.00
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 6 pages with 4 Questions only.
2. Attempt all **FOUR** questions. The distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) Name **TWO** (2) types of light emitting diode (LED) devices that are used in optical fiber communications.

[2 marks]

(b) With the aid of energy band diagrams (unbiased and forward biased) explain the basic principle of a light emitting diode (LED). Explain how applied forward bias voltage (V) allow the electrons become injected or diffused from n^+ side to the p^- side of an LED device.

[8 marks]

(c) FIGURE Q1(c)(i) and Q1(c)(ii) show two types of LED structures.

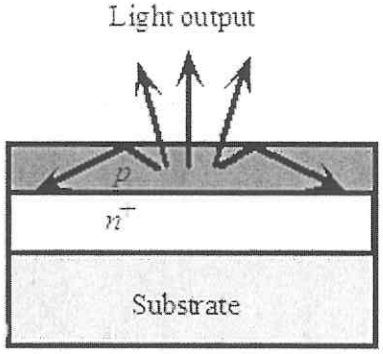


FIGURE Q1(c)(i)

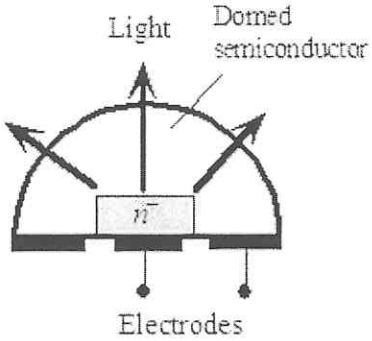


FIGURE Q1(c)(ii)

(i) Describe the problem faced by the LED structure shown in FIGURE Q1 (c)(i).

[3 marks]

(ii) Explain how the dome shape as seen in the LED structure in FIGURE Q1(c ii) solves the problem described in Question 1 (c)(i).

[3 marks]

(iii) Although the LED structure in Figure Q1(c)(ii) is structurally better, it is difficult to fabricate and more expensive. Suggest a more economical solution.

[3 marks]

(d) Based on radiative and non-radiative recombination define and quantify the internal and external efficiency of an LED with relevant equations.

[6 marks]

Continued...

Question 2

(a) In a homojunction laser diode, what is the condition that allows lasing radiation to occur? You may consider a 3 level system for your explanation.

[5 marks]

(b) With the help of a suitable graph, illustrate the typical optical power output vs. forward current for a LED and a laser diode.

[2 marks]

(c) In a double heterostructure diode, why is it important that the active layer is a thin layer?

[3 marks]

(d) What is the advantage of an AlGaAs/GaAs heterojunction?

[2 marks]

(e) (i) With the help of a suitable diagram, illustrate the structure of a double heterostructure laser diode using two different bandgap semiconductors which are GaAs ($E_g \approx 1.4$ eV) and AlGaAs ($E_g \approx 2$ eV).

[2 marks]

(ii) Sketch a simplified energy band diagram (with clear labelling including the electron in the conduction band and holes in the valence band) for a double heterostructure laser diode in the presence of a large forward bias. Explain where the lasing recombination takes place.

[3 marks]

(f) Consider an AlGaAs-based heterostructure laser diode that has an optical cavity with a length of 200μn. The peak radiation is at 870 nm and the refractive index of GaAs is about 3.6. Calculate the mode integer m of the peak radiation and the separation between the modes of the cavity. If the optical gain vs. wavelength characteristics has a full width at half maximum (FWHM) wavelength width of about 6 nm, how many modes are there within this bandwidth? Assume that the refractive index n does not change significantly with wavelength from one mode to another.

[8 marks]

Continued...

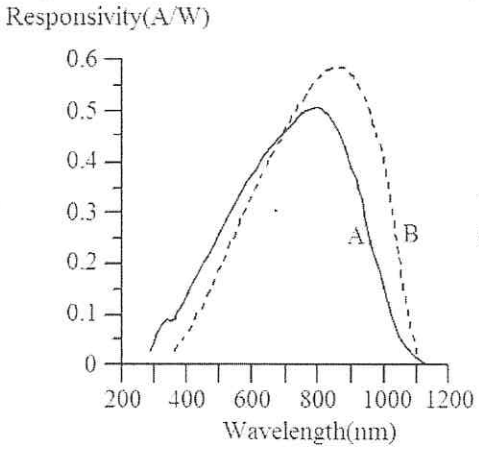
Question 3

(a) Describe **TWO** (2) desirable properties of a photodetector. [4 marks]

(b) The responsivity of a photodetector will vary with changes in certain parameters. Name **TWO** (2) of these parameters. [2 marks]

(c) Explain the **THREE** (3) different ways to increase the quantum efficiency (QE) of a photo detector device. [3 marks]

(d) Consider two commercial silicon (Si) (*pin*) photodiodes, type A and type B, both classified as fast (*pin*) photodiodes, with their responsivity shown in FIGURE 3(d) below. The photosensitive area is 0.125 cm^2 (4 mm in diameter).



The responsivity of two commercial Si *pin* photodiodes

FIGURE 3(d)

(i) Explain why the photodiodes have different responsivity. [2 marks]

(ii) Calculate the photocurrent from each type of photodiode when they are illuminated with infrared light of wavelength 1000 nm and light intensity 1 μWcm^{-2}. [5 marks]

(iii) Calculate the quantum efficiency of each photodiode. [5 marks]

(iv) What is the quantum efficiency for an ideal photodiode? Sketch the responsivity versus wavelength curve for an ideal photodiode. [4 marks]

Continued...

Question 4

(a) What is solar constant or air-mass one (AM1)? [2 marks]

(b) With the aid of a diagram illustrate the basic structure of a photovoltaic device. What are the **FOUR** (4) basic steps in the operation of a solar cell? [6 marks]

(c) A silicon solar cell of area 4 cm^2 is connected to drive a load R. It has the I-V characteristics shown in FIGURE 4(c) under an illumination of 1000 W m^{-2}. Suppose that the load is 20 Ω and it is used under a light intensity of 1 kW m^{-2}.

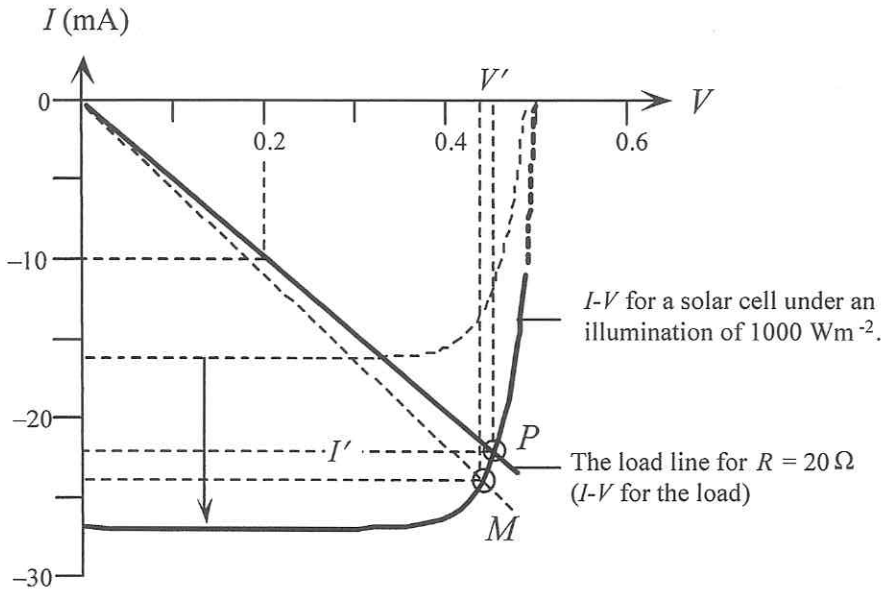


FIGURE 4(c)

(i) Calculate the power delivered to the load. [2 marks]

(ii) Calculate the input sun-light power. [2 marks]

(iii) Calculate the efficiency of the solar cell in this circuit. Comment on the efficiency of the solar cell. [3 marks]

Continued...

(d) What are the **THREE** (3) main reasons for the series resistance in a solar cell?

[3 marks]

(e) Explain how the fill factor (FF) in conjunction with the open circuit voltage and short circuit current is used to determine the maximum power from a solar cell.

[2 marks]

(f) Tandem cells uses 2 or more cells in cascade to improve the efficiency of a solar cell. With the aid of a suitable diagram, describe the working principle of a tandem solar cell.

[5 marks]

Useful constants:

Speed of light:	$c = 3.0 \times 10^{8}$ m/s
Electronic charge:	$e = 1.6 \times 10^{-19}$ C
Planck's constant:	$h = 6.63 \times 10^{-34}$ Js
Permittivity in vacuum:	$\varepsilon_o = 8.85 \times 10^{-14}$ F/cm
Permeability in vacuum:	$\mu_o = 4\pi \times 10^{-7}$ H/m
Free electron mass:	$m_o = 9.11 \times 10^{-31}$ kg
Boltzmann's constant:	$k_B = 1.3806 \times 10^{-23}$ J/K
Thermal voltage:	$V_t = kT/e = 0.0259$ V

End of Paper